Official File Copy

Reprinted from

MARINE POLLUTION AND SEA LIFE

Published December 1972 by

Fishing News (Books) Ltd., 23 Rosemount Avenue, West Byfleet, Surrey

Waterfront Housing Developments: Their Effect on the Ecology of a Texas Estuarine Area*

W. L. Trent, E. J. Pullen and D. Moore†

La construction de logements sur le littoral: ses incidences sur l'écologie d'une zone estuarine au Texas

En 1969, on a effectué des études destinées à comparer l'écologie d'une zone estuarine naturelle (marais et baie) avec celle d'une zone estuarine adjacente modifiée par le creusement de canaux, le cloisonnement et l'assèchement. Dans chaque zone, on a étudié périodiquement par sondage, de mars à octobre, les facteurs hydrographiques, les poissons, les crustacés et les macro-invertébrés benthiques. On a mesuré les taux de fixation, de croissance et de mortalité des huîtres juvéniles (*Crassostrea virginica*) durant les mois de février à octobre et déterminé la productivité du phytoplancton du mois de juin au mois d'août.

Les taux de concentration de l'oxygène, des nitrites et de l'azote (méthode de Kjeldahl) étaient nettement plus élevés dans la zone naturelle, tandis que le taux de phosphate total était nettement plus élevé dans la zone modifiée. Bien que l'on ait dénombré au chalut 64 espèces de poissons et de crustacés, six d'entre elles représentaient 88,8 pour cent du total des prises. *Brevoortia patronus*, *Anchoa mitchilli* et *Micropogon undulatus* étaient les plus abondantes dans la zone modifiée: *Penaeus aztecus*, *P. setiferus* et *Leiostomus xanthurus* étaient les plus abondantes dans la zone naturelle. Le taux de fixation d'un essaim d'huîtres était 14 fois plus élevé dans le milieu naturel que dans la zone modifiée et le taux de croissance des jeunes huîtres était 1,8 fois plus rapide. La mortalité des huîtres était sensiblement plus élevée dans la zone modifiée pendant l'été.

La production brute de phytoplancton dans les eaux de surface atteignait en moyenne 2,24, 2,06 et 1,17 mg de carbone par litre et par jour dans la zone modifiée, dans le marais et dans la baie respectivement. Dans une partie de la zone modifiée, la production extrêmement forte de phytoplancton, responsable du faible taux d'oxygène dissous, a provoqué une réduction de l'abondance des poissons et des invertébrés pendant l'été.

Urbanizaciones a orillas del mar: sus efectos en la ecología de un estuario de Texas

Durante 1969 se hicieron estudios comparativos de la ecología de una zona de estuario natural (pantano y bahía) y la de otra adyacente alterada por la construcción de canales, muros de contención y rellenos. Desde marzo hasta octubre se hicieron en cada zona muestreos periódicos de factores hidrográficos, peces, crustáceos y macro-invertebrados bentónicos. De febrero a octubre se midieron los ritmos de fijación, crecimiento y mortandad de ostras juveniles (*Crassostrea virginica*) y de junio a agosto se determinó la productividad del fitoplancton.

Los índices de oxígeno, nitrito y nitrógeno (determinado por el método Kjeldahl) fueron sensiblemente mayores en la zona natural, en tanto que en la alterada fue bastante mayor el fósforo total. Si bien se recogieron con artes de arrastre 64 especies de peces y crustáceos, sólo seis de ellas constituían el 88,8 por ciento de la captura total. Las más abundantes especies en la zona alterada fueron *Brevooritia patronus*, *Anchoa mitchilli* y *Micropogon undulatus*, y en la zona natural, *Penaeus aztecus*, *P. setiferus* y *Leiostomus xanthurus*. Los ritmos de fijación de larvas de ostras y de crecimiento de ostras juveniles fueron 14 y 1,8 veces mayores respectivamente en la zona natural que en la alterada. La mortandad de las ostras era sensiblemente mayor en la zona alterada durante el verano.

La producción bruta de fitoplancton en las aguas superficiales alcanzó un promedio de 2,24, 2,06 y 1,17 mg de carbono por litro y por día en las zonas alterada, pantanosa y de bahía, respectivamente. En una parte de la zona alterada, la extraordinariamente elevada producción de fitoplancton que era motivo de que hubiera poco oxígeno disuelto, redujo la abundancia de peces e invertebrados durante el verano.

ESTUARIES along the United States coastline are being altered extensively by Federal, State and private institutions. More than 81,000 ha of shallow coastal bays (excluding marshes) in the Gulf of Mexico and South Atlantic areas have been altered over the past 20 years (Chapman, 1968). In Texas deepening of about 700 mi of Federal navigation channels has altered 5,265 ha of bay bottom and destroyed 2,830 ha of brackish marsh and the dredged spoil has filled 2,025 ha of shallow bay and covered 9,315 ha of brackish marsh. Presently, large areas of shallow bays and marshes are being developed for waterfront housing sites (fig 1). This involves dredging, bulkheading and filling. With expanding human populations and increased leisure time it is likely that the demand for these areas will increase.

When areas of shallow marsh and bay are deepened or filled with spoil major changes in the bayshore environment include: (1) reduction in acreage of shore zone and

* Contribution No. 311 from the National Marine Fisheries Service Biological Laboratory, Galveston, Texas 77550, U.S.A.
† National Marine Fisheries Service Biological Laboratory, Galveston, Texas 77550, U.S.A.

marsh vegetation, (2) changes in marsh drainage patterns and nutrient inputs and (3) changes in water depth and substrates. The effects of these changes on estuarine organisms are poorly understood.

Our studies compare natural and altered areas with respect to: (1) substrates, (2) selected hydrographic variables, (3) phytoplankton productivity, (4) relative abundance of benthic macro-invertebrates, fishes and crustaceans, and (5) the setting, growth and mortality rates of the American oyster (*Crassostrea virginica*).

Study area and methods

The study area, located in West Bay, Texas (near Galveston Bay system) included a natural marsh, an open bay area, and a canal area that was similar to the natural marsh before it was altered by channellization, bulkheading and filling (fig 1). The developed area, which originally comprised about 45 ha of emergent marsh vegetation, intertidal mud flats and subtidal water area was increased to about 32 ha of subtidal water area with a water volume of (mean low tide level) about 394,000 m^3 compared to the original 184,000 m^3.

Hydrographic measurements, fish and crustacean samples were taken the same day (between 10.00 h and 14.00 h) and night (between 22.00 h and 02.00 h) at 2-week intervals from 25 March to 21 October 1969, at ten stations (fig 1). Sediment samples were taken to determine the percentage composition of sand, silt and clay water. Samples were taken 30 cm above the bottom. Fishes and crustaceans were collected in a trawl that had a mouth opening of 0.6 m by 3 m and a stretched mesh of 28 mm in the body and 2.5 mm in the codend. At each station the trawl was towed over a distance of 200 m at 2 kn.

Primary productivity was determined twice each month at five stations (1, 2, 6, 7 and 10) in June, July and August using the light- and dark-bottle technique

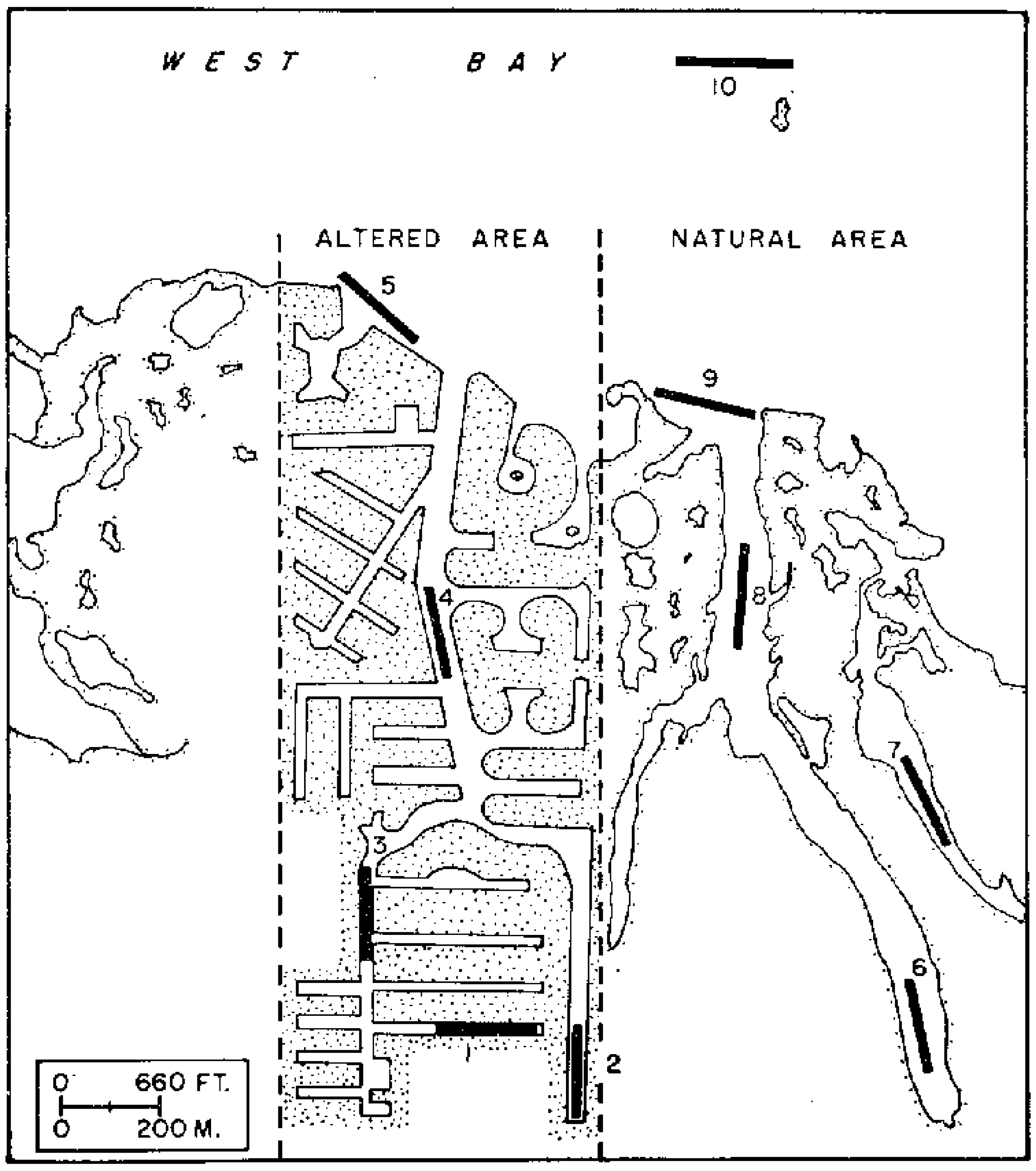

Fig 1. The Galveston Bay system showing the study area and station locations in West Bay, Texas

described by Gaarder and Gran (1927). Water samples were taken 15 cm below the surface and incubated 24 h.

Benthic macro-invertebrates were sampled at 2-week intervals from 25 March to 21 October at six stations. Two stations (1 and 4) were in the canals, three (6, 7, 8) were in the natural marsh, and one (10) was in the open bay (fig 1). Cores of the substrate were taken with a metal cylinder 14 cm long and 9.6 cm in diameter. The number and volume of organisms, percentage of total carbon and the volume of detrital vegetation in the substrate were determined in each sample.

Oyster spatfall, growth, and mortality rates were monitored at stations 1 and 6 from February 1969 to February 1970. Asbestos plates were used to collect spatfall. Eight size groups of juvenile oysters were placed in trays at each station and total lengths of the oysters were determined every 4 weeks. Dead oysters were replaced every 2 weeks with oysters of similar size.

Substrate and hydrology

Substrates in the canals, marsh, and bay were distinctly different (fig 2). Sediments in the canals contained more silt and clay (41 per cent) than in the marsh (31 per cent). The lowest silt and clay contents occurred in the undredged bay area (17 per cent). In a similar study in Boca Ciega Bay, Florida, Taylor and Saloman (1968) found sediments in undredged areas averaged 94 per cent sand and shell and those in dredged canals averaged 92 per cent silt and clay. Values of total carbon in the sediments were highest in the canals and lowest in the bay, but the differences were not great. The amount of detrital vegetation on and in the substrates was more than twice as great in the marsh as in the canals. Detritus was almost absent in the bay.

Average temperature, salinity, total alkalinity and pH differed only slightly between areas (fig 3). The average and range of dissolved organic nitrogen were highest in the marsh. A major part of the nitrogen in the marsh may have originated from cattle grazing adjacent to this area. Total phosphorus was highest, and had the greatest range, in the canals and possibly originated in runoff from fertilized lawns and seepage from septic tanks.

Average values of nitrogen and phosphorus were much lower in West Bay than had been previously found in Clear Lake (Pullen, 1969); and in upper Galveston Bay (Pullen and Trent, 1969), probably because domestic and industrial wastes are not discharged into the middle area of West Bay. Clear Lake is a heavily populated area, with inadequate sewage treatment facilities and upper Galveston Bay receives domestic and industrial waste from the City of Houston via the Houston Ship Channel.

Average turbidity of bottom waters (Jackson turbidity unit—JTU) was highest in the bay, but the highest values were measured in the canals. In surface water samples, however, turbidities were over twice as high in the marsh and bay as in the canals. These observations agree with those reported by Taylor and Saloman (1968).

Average values of dissolved oxygen were highest in the bay, intermediate in the marsh, and lowest in the canals. During the summer, oxygen dropped to critically low levels (less than 0.2 ml/l) at the three stations (1, 2 and 3) farthest from the bay. The annual average at stations 1, 2 and 3 was 3.17 compared with 4.39 ml/l for stations 4 and 5 nearer the bay. Taylor and Saloman (1968) stated

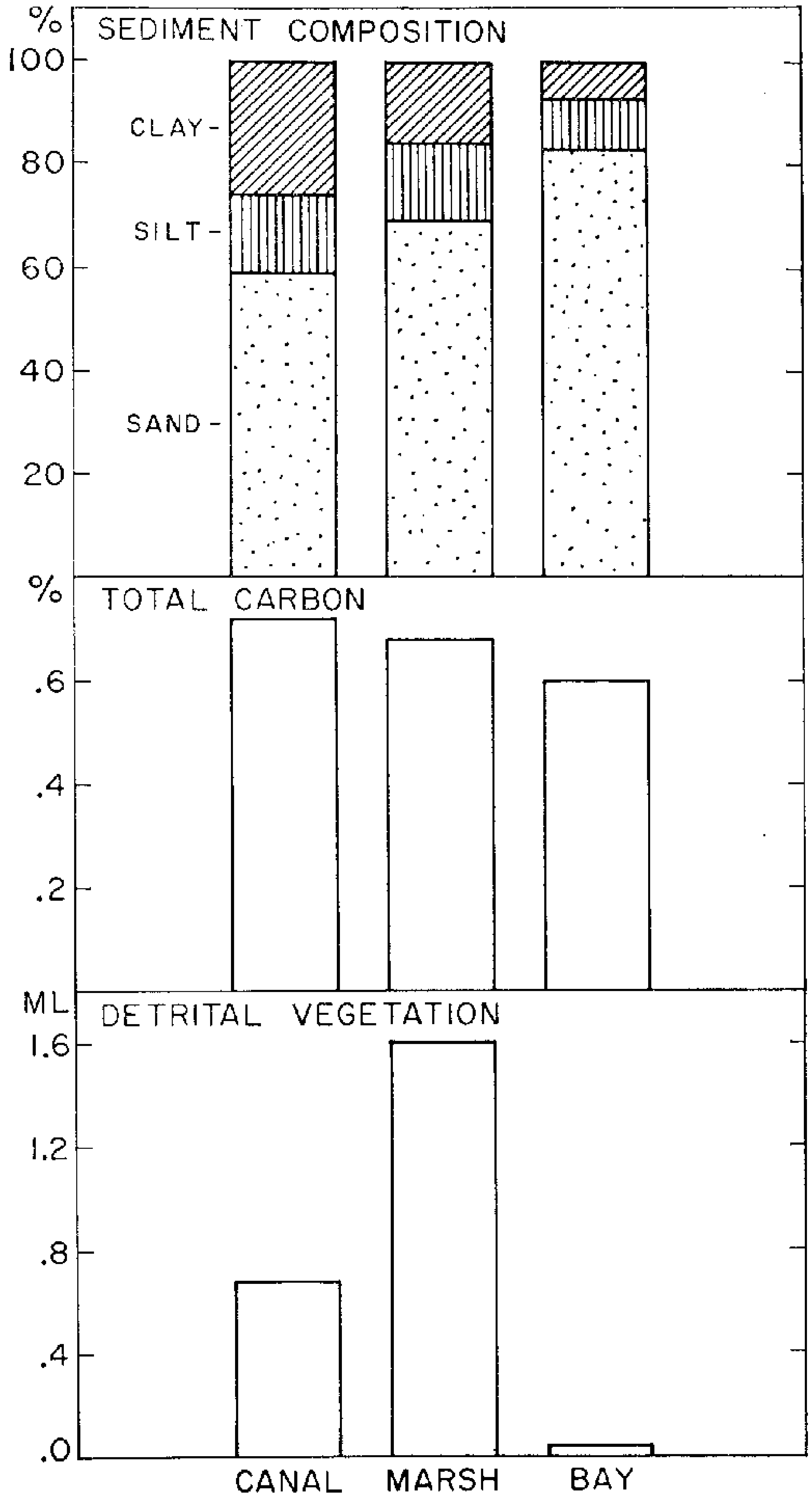

Fig 2. Comparisons of sediment composition, total carbon, and detrital vegetation between the canals, marsh and bay

that oxygen levels were reduced during the summer over the soft sediments of housing development canals.

Phytoplankton

Phytoplankton productivity in the West Bay area was high compared with other marine environments. Gross photosynthesis was 1.96 mg C/l day and respiration was 0.51 mg C/l day; the values ranged from 0.87 to 3.43 for photosynthesis and 0.23 to 1.19 for respiration. The average values were much higher than those reported by Williams (1966) for shallow estuaries along the Atlantic coast. At the 50 per cent insolation depth, his mean values were 0.50 mg C/l day for gross photosynthesis and 0.19 for respiration. The differences were even greater than indicated because, according to Williams, the rate of photosynthesis at the depth (about 50 cm in our area) of 50 per cent insolation is higher than at a depth of 15 cm. Net photosynthesis in the Atlantic coast estuaries was greater than most of the values from other marine environments (Williams, 1966).

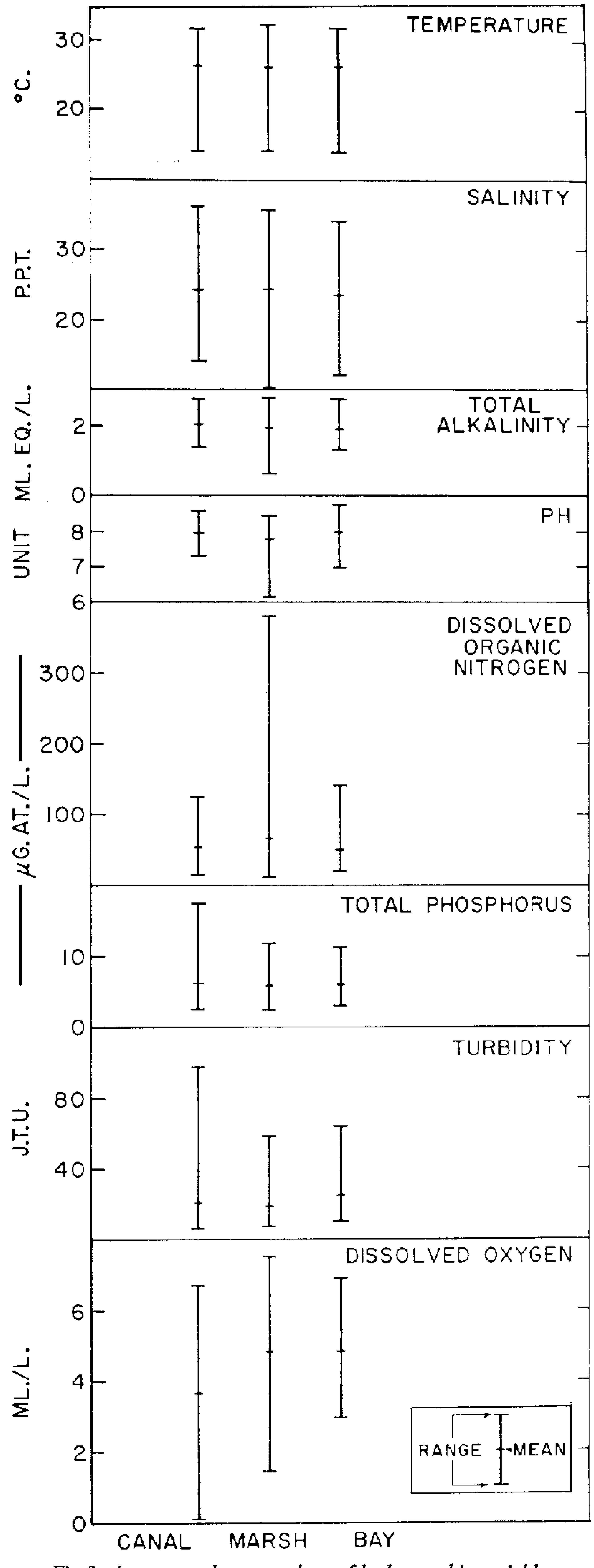

Fig 3. Average and range values of hydrographic variables observed in the canals, marsh and bay

Average gross photosynthesis rates for June, July and August ranged from 1.17 mg C/l day in the bay to 2.25 in the canals (fig 4). Average values at the canal stations were almost identical as were those at the two marsh

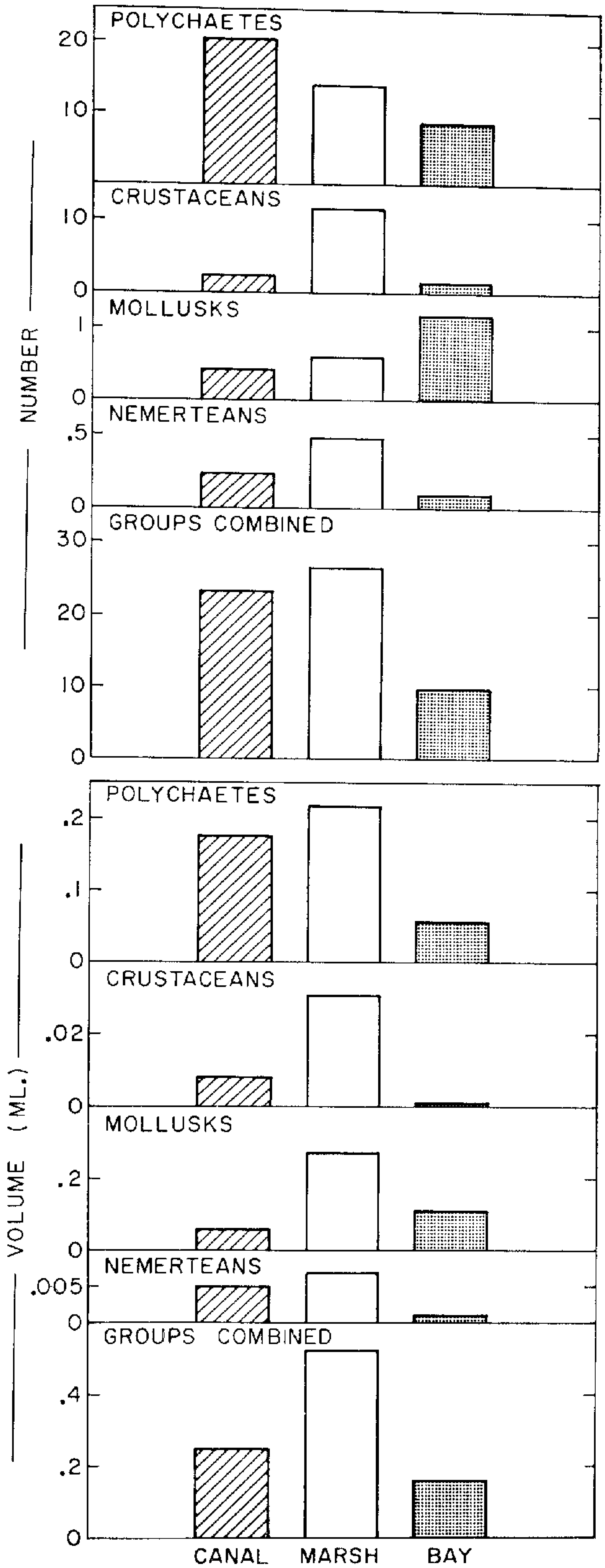

Fig 4. Gross and net photosynthesis, and respiration by area and date, and average values for all sampling dates

stations. Average photosynthesis in the canals was slightly higher (8 per cent) than in the marsh and much higher (49 per cent) than in the bay. Taylor and Saloman (1968) reported that primary production of phytoplankton

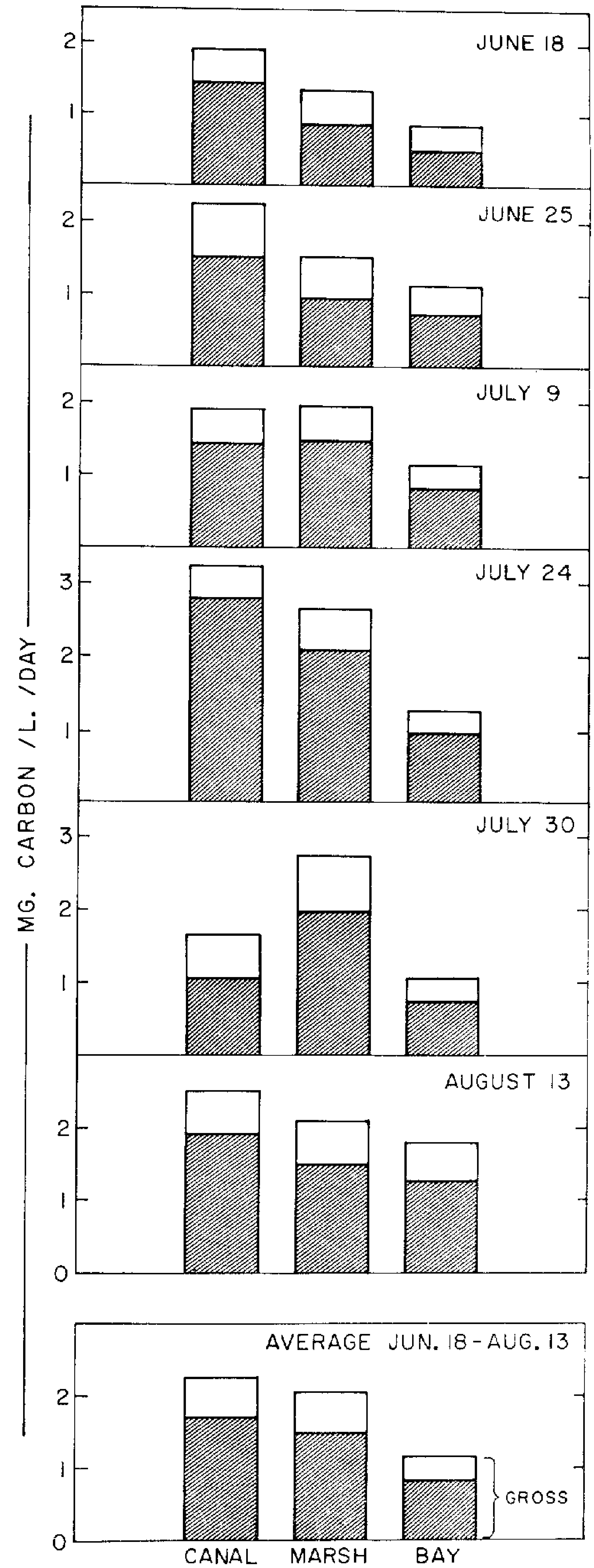

Fig 5. Average number and volume of benthic macro-invertebrates collected per 800 cm² of bottom material by area, taxonomic group, and for groups combined

did not differ consistently between development canals and open bay areas.

Benthic macro-invertebrates

Polychaetes comprised 66 per cent of the number and 44 per cent of the volume of benthic animals caught. Crustaceans were second in number (29 per cent) but lowest in volume (4 per cent). Molluscs were third in abundance (3 per cent), but second in volume (41 per cent). The volume of molluscan biomass was much lower than this indicates, however, because the volume includes shells. Nemerteans were lowest in number (1 per cent) and third in volume (11 per cent).

Benthic animals were slightly more abundant numerically and about twice as abundant volumetrically in the marsh as in the canals; they were least abundant in the bay (fig 5). The order of abundance varied, however, when individual groups were considered. Capitellidae were the dominant organisms caught (91 per cent of all polychaetes collected) and were most abundant in the marsh and canals where substrates were largely silt, clay and detritus. Individuals of this family burrow through the substrate and obtain their food by ingesting organic matter in the sand and mud (Barnes, 1963). Crustaceans, most of which belonged to the families Ampeliscidae and Corophiidae (99 per cent of all crustaceans collected and identified), were over three times as abundant in the marsh as in the other two areas. Molluscs, mostly the genera *Tellina*, *Tagelus* and *Mulinia* (95 per cent of all molluscs collected), were numerically most abundant in the bay although volumetrically, the marsh had the highest standing crop. Nemerteans were most abundant in the marsh and least abundant in the bay.

Oyster spatfall, growth and mortality

About 14 times more oyster spat attached to sampling plates in the marsh than in the canal during the 12-month period. On a 600 cm^2 surface area, 184 attached in the marsh and 13 in the canals. These rates were much lower than those observed by Hopkins (1931) in West Bay.

Juvenile oysters, 44 mm in average total initial length, achieved a yearly average increase in shell length of 52 mm in the marsh, 72 per cent faster than the 33 mm achieved in the canals. Growth in the marsh was similar to the average for Texas given by Hofstetter (1965) who estimated that it takes from 18 to 24 months for oysters to reach a length of 76 mm.

The annual rate of mortality averaged 91 per cent in the canals and 52 per cent in the marsh. In a nearby area (Louisiana) of similar climate, Mackin (1961) noted that the normal annual loss of oyster, 1 year and older, was between 50–70 per cent and might run as high as 90 per cent or as low as 30 per cent. On this basis the mortality of oysters in the marsh was a "low average mortality" whereas oyster mortality in the canals was slightly above the "high extreme mortality" observed in the Louisiana studies.

Fishes and crustaceans

Sixty-four species and 240,575 specimens of finfish and crustaceans were taken with the trawl. Of the 64 species, 54 occurred in the marsh, 52 in the canals and 44 in the bay. In terms of numbers of all species caught the marsh was the most productive area and the canals the second most productive. The average number of animals caught per tow was 951 in the marsh, 659 in the canals and 412 in the bay.

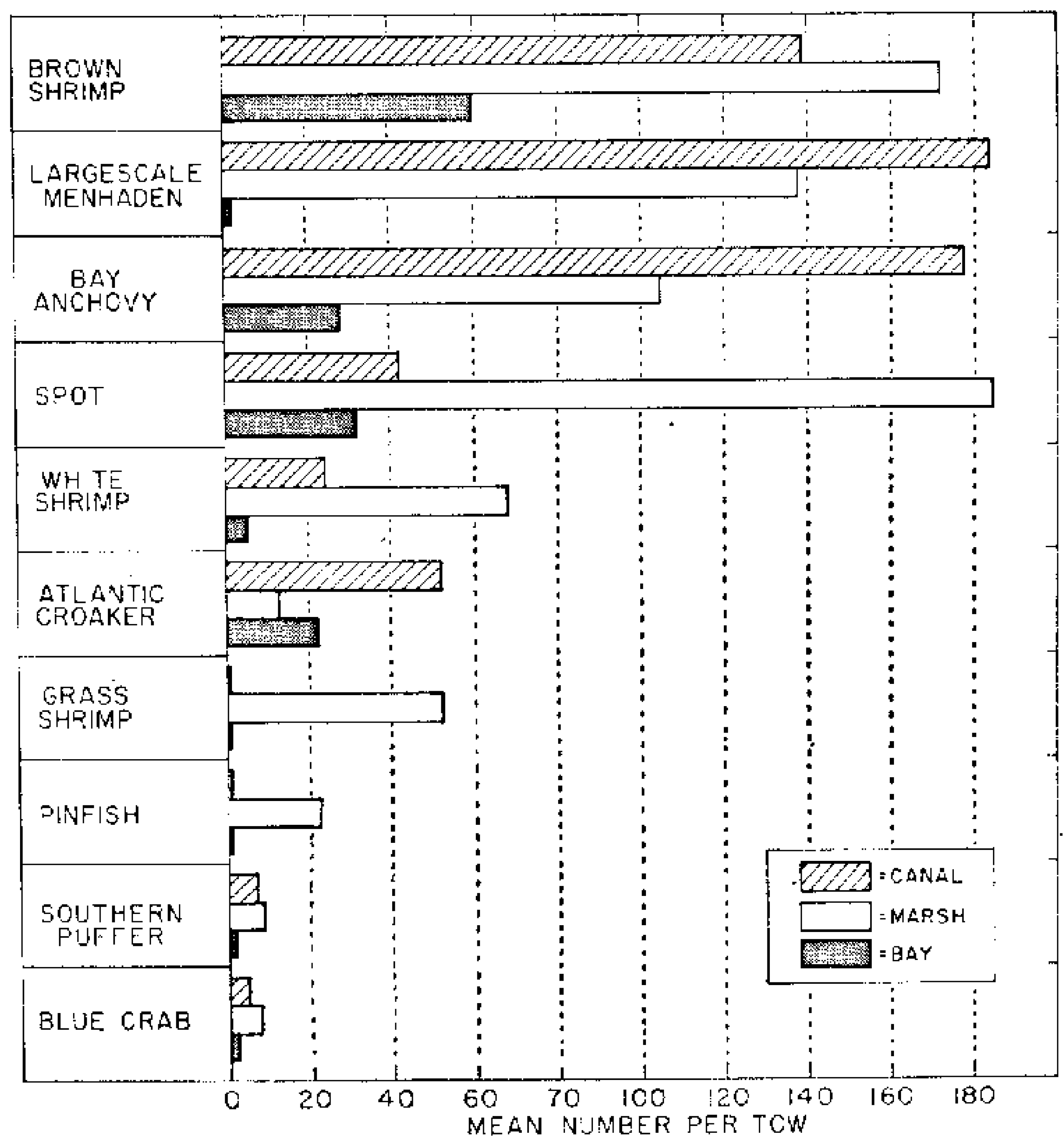

Fig 6. The 10 species caught in greatest abundance in the trawl, with comparisons of their abundance between canals, marsh and bay

The ten most abundant species represented 96 per cent of the total number of specimens (fig 6). Of the six most abundant species (89 per cent of the total catch), brown shrimp (*Penaeus aztecus*), white shrimp (*P. setiferus*), spot (*Leiostomus xanthurus*), large scale menhaden (*Brevoortia patronus*) and Atlantic croaker (*Micropogon undulatus*) are commercially valuable and the bay anchovy (*Anchoa mitchilli*) is important as food for commercial and sport fish species. The first three species were most abundant in the marsh and the last three were most abundant in the canals.

Brown shrimp, the most valuable commercial fishing species in the United States were more abundant in the canals and marsh, probably because of bottom type and food availability. Bottom sediments in these areas contained more silt and clay, vegetative material and total carbon than in the bay (fig 2). Juvenile brown shrimp feed mainly on detrital material and benthic organisms and prefer soft, muddy substrates with large amounts of detrital material (Williams, 1958). Benthic organisms were more abundant and phytoplankton productivity was higher, in the marsh and canals than in the open bay. Williams (1955) reported that stomachs of brown shrimp from estuarine areas along the Atlantic coast contained, in order of decreasing frequency of occurrence, masses of unrecognizable debris, chitin fragments of crustaceans, setae and jaws of annelids, plant fragments and sand.

Large scale menhaden and bay anchovy are plankton feeders during their juvenile stages. Menhaden feed predominantly on phytoplankton, and anchovy mostly on zooplankton (Darnell, 1958). The abundance of these fishes in the three areas was related, although not proportionately, to phytoplankton productivity in the areas (fig 4).

Juvenile spot were about four times more abundant in the marsh than in the canals and open bay. This is probably related to the high abundance of crustaceans

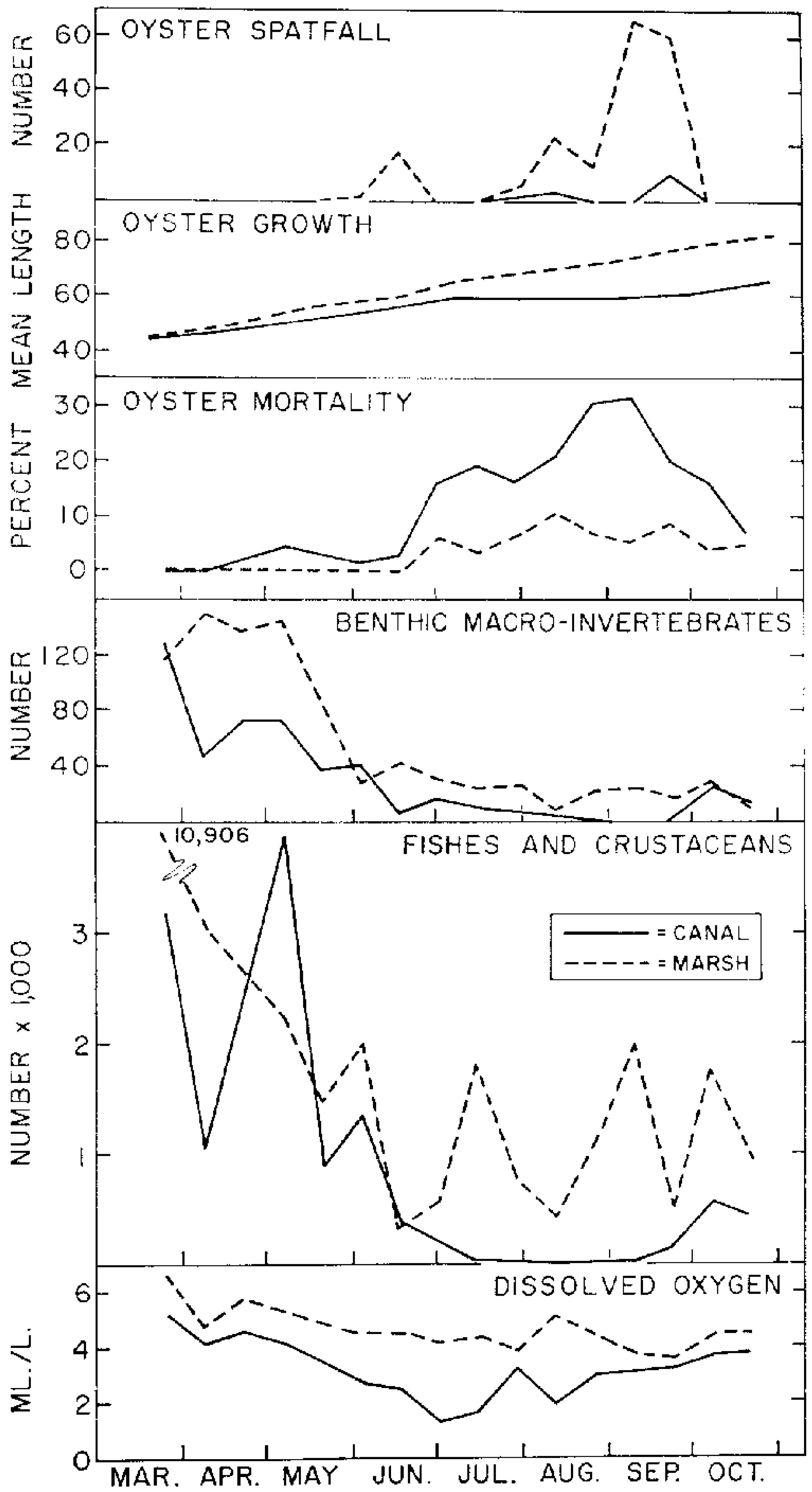

Fig 7. Oyster spatfall, growth and 2-week mortality rates, abundance of benthic organisms, total number of fish and crustaceans caught, and dissolved oxygen by date at stations 1 in the canal and 6 in the marsh

(fig 5) in the marsh area. In general, juvenile spot feed predominantly on planktonic and benthic micro-crustaceans (Gunter, 1945; Darnell, 1958).

White shrimp show a more distinct preference than brown shrimp for shallow water habitats characterized by muddy or peaty bottoms high in organic detritus and an abundance of marsh grasses (Weymouth, Lindner and Anderson, 1933; Williams, 1955; Loesch, 1965; Mock, 1967). These factors, along with those discussed previously for brown shrimp, are important in explaining the observed distribution of white shrimp.

Atlantic croakers were most abundant in the canals and least abundant in the marsh. Why they were so is difficult to explain. Juvenile croakers prefer soft substrates where they can obtain much of their food by digging for subsurface invertebrates and organic debris (Roelofs, 1954; Reid, 1955). This type of substrate was not present in the bay.

Seasonal relations

Seasonal relations between levels of dissolved oxygen, spatfall, growth and mortality rates of oysters, abundance of benthic organisms and fishes and crustaceans at stations 1 in the canal and 6 in the marsh are shown in fig 7. Oxygen levels were even more critical at station 1 than the figure indicates because: (1) the data were taken at a time of day that was not the most critical (about 06.00 h); and (2) in our regular schedule we did not sample during times of heavy plankton blooms. Other observations revealed, however, that plankton blooms sufficient to reduce oxygen levels to zero at night occurred at least four times at station 1 during June–August.

Poor oyster growth, high oyster mortality and low to nil standing crops of benthic organisms, fishes and crustaceans during June–September were probably directly or indirectly caused by low oxygen levels at station 1. Stations 2 and 3 in the area of the development farthest from the bay had low oxygen levels during the summer and a smaller than average standing crop of fishes and crustaceans. We think poor water circulation in parts of the development canals caused conditions favourable for high populations of phytoplankters.

Conclusions

In general, productivity was highest in the marsh, intermediate in the canals of the altered area and lowest in the open bay. Productivity in the canals would probably have been much higher if dissolved oxygen levels had been higher during the summer.

The standing crops of benthic organisms, fishes and crustaceans in the altered area were high and we are planning studies to determine the relative contributions of vegetative material by various primary producers. We know that phytoplankton, attached algae, and mud diatoms are produced in the altered area. In addition, submerged sea grasses and emergent vegetation (dominated by *Spartina alterniflora*) grow in the natural marsh. We do not know, however, whether the altered area is self-supporting in terms of vegetative productivity or derives much of the vegetative detritus from the natural marsh through tidal action. If the altered area is not self-supporting and if areas of marsh are developed in ways similar to the present, then biological productivity of the estuarine zone will be reduced in relation to the acres of marsh altered.

References

BARNES, R D Invertebrates zoology. Philadelphia, W B Saunders 1963 Co., 632 p.

CHAPMAN, C Channelization and spoiling in Gulf coast and South 1968 Atlantic estuaries. *In* Proceedings of the Marsh and Estuary Management Symposium, Louisiana State University, pp. 93–106.

DARNELL, R M Food habits of fishes and larger invertebrates of 1958 Lake Pontchartrain, Louisiana, an estuarine community. *Publs Inst. Mar. Sci. Univ. Tex.*, (5):353–416.

GAARDER, T and GRAN, H H Investigations of the production of 1927 plankton in the Oslo Fjord. *Rapp.P.-v. Reun. Cons. Perm. int. Explor. Mer.*, 42:1–48.

GUNTER, G Studies on marine fishes of Texas. *Publs Inst. Mar. Sci.* 1945 *Univ. Tex.*, (1):1–190.

HOFSTETTER, R P The Texas oyster fishery. *Bull. Tex. Parks Wildl.* 1965 *Dep.*, (40):1–39

HOPKINS, A E Factors influencing the spawning and setting of 1931 oysters in Galveston Bay, Texas. *Bull. Bur. Fish., Wash.*, (47):57–83.

LOESCH, H Distribution and growth of penaeid shrimp in Mobile 1965 Bay, Alabama. *Publs Inst. mar. Sci. Univ. Tex.*, (10):41–58.

MACKIN, J G A method of estimation of mortality rates in
1961 oysters. *Proc. natn. Shellfish. Ass.*, 50(1959):41–51.

MOCK, C R Natural and altered estuarine habitats of penaeid
1967 shrimp. *Proc. Gulf. Caribb. Fish. Inst.*, 19(1966):86–98.

PULLEN, E J Hydrological conditions in Clear Lake, Texas, 1958–
1969 66. *Spec. scient. Rep. U.S. Fish Wildl. Serv. (Fish)* (578): 8 p.

PULLEN, E J and TRENT, L Hydrographic observations from the
1969 Galveston Bay system, Texas, 1958–67. *Data Rep. U.S. Fish Wildl. Serv. (microcards)* (31):1–151.

REID, G K A summer study of the biology and ecology of East
1955 Bay, Texas. Part 2. The fish fauna of East Bay, the Gulf beach, and summary. *Tex. J. Sci.*, 7:430–53.

ROELOFS, E W Food studies of young sciaenid fishes *Micropogon*
1954 and *Leiostomus*, from North Carolina. *Copeia*, 1954 (2): 151–3.

TAYLOR, J L and SALOMAN, C H Some effects of hydraulic dredg-
1968 ing and coastal development in Boca Ciega Bay, Florida. *Fishery Bull. U.S. Fish Wildl. Serv.*, 67:213–42.

WEYMOUTH, F W, LINDNER, M J and ANDERSON, W W Prelim-
1933 inary report on the life history of the common shrimp, *Penaeus setiferus* (Linn.). *Bull. Bur. Fish., Wash.*, (48):1–26.

WILLIAMS, A B A contribution to the life histories of commercial
1955 shrimps (Penaeidae) in North Carolina. *Bull. mar. Sci. Gulf Caribb.*, 5:117–46.

WILLIAMS, A B Substrates as a factor in shrimp distribution.
1958 *Limnol. Oceanogr.*, 3:283–90.

WILLIAMS, R B Annual phytoplanktonic production in a system of
1966 shallow temperate estuaries. *In* Some contemporary studies in marine science, edited by Harold Barnes. London, George Allen & Unwin Ltd., pp. 699–716.